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(11) (C) **2,040,076**

(22) 1991/04/09

(43) 1991/10/12

(45) 1995/11/14

(52) 181-14

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(51) Int.Cl.[5] E04B 1/84

(19) (CA) **CANADIAN PATENT** (12)

(54) Sound Absorbing Panel

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1990/04/11

(57) 16 Claims

2040076

ABSTRACT

A sound absorbing panel includes Helmholtz-resonators of different resonance frequencies on a surface which is adapted to face a sound source. All Helmholtz-resonators located within the sphere of activity of a Helmholtz-resonator of a relatively lower resonance frequency have resonance frequencies which are mutually different and different from that of the lower frequency resonator. The Helmholtz-resonators cover the whole area of the panel. The walls of the resonators as well as the whole of the surface which supports the resonators is constructed as an absorber sheet. The openings of the resonators are kept uncovered. The resonators and the absorber sheet are made of the same material. The sound absorbing panel may be easily manufactured, provides an improved sound absorption and has small overall dimensions.

SOUND ABSORBING PANEL

The invention relates to a sound absorbing panel which has acoustic resonators of different resonance frequencies on a surface of the panel that faces a sound source to be attenuated.

Such panels are known from a published German patent application DE 2,456,916. The sound absorbing panels are used for lining compartments, especially for the interior lining of motor vehicle passenger compartments or the driver's cabins of heavy machinery. The above-referenced published application teaches the combination of a conventional liner with an additional layer to produce a liner having a hollow body. The hollow body acts like a Helmholtz-resonator through the provision of a conduit connecting the interior of the hollow body with the ambient air. The application further teaches the provision of two, three or more additional Helmholtz-resonators on the surface of the lining element, which resonators are adjusted to different frequencies in accordance with the well known Helmholtz equation of acoustics. The purpose of such a construction is the reduction of the sound pressure over the whole of that range of frequencies which is influenced by standing waves. The liners are compartmented to provide laterally adjacent Helmholtz resonators of large volume. It is a disadvantage of such a liner that it is very voluminous, since it must be ensured that resonators of the same resonance frequency are positioned sufficiently apart to prevent an overlap of their spheres of activity. Such an overlap would substantially reduce the sound absorbing efficiency of the liner. Besides, the spacing required for these resonators causes problems, since there is not enough space in most compartments for the provision of a large number of resonator elements, required to cancel a wide range of frequencies.

German patent 2,515,127 describes a large number of closely positioned hollow resonators of equal cross-sectional area and different lengths. The resonators have a common end wall which is

positioned at an angle to the plane of the sound entry openings of the resonators to provide resonators of different length. Therefore, resonators which are directly adjacent each other are of identical shape and size and are located in the same plane.

In German published application 3,615,360, a sheet absorber is described which comprises a contoured sheet including completely sealed air chambers that are positioned side by side and are separated by webs. The friction damping which occurs during bending vibrations in the walls and the cover sheet of the air chambers is used to achieve acoustic damping.

In view of the above described prior art related to the principals of Helmholtz-resonators, a sound absorbing panel is desired which requires distinctly less space per resonator, especially in terms of the thickness of a panel. Furthermore, it is desirable that the sound absorbing panel has resonance and, thus, damping characteristics which are as constant as possible in the frequency range between about 16 Hz and 2.5 kHz. It is also desirable for the sound absorbing panel to be produced with only a few different materials using a single manufacturing process.

Accordingly, the invention provides a sound absorbing panel, which has Helmholtz-resonators of different resonance frequencies on a surface adapted to be oriented towards a sound source. The Helmholtz-resonators are positioned on the panel so that adjacent resonators have different resonance frequencies, and resonators of the same frequency are spaced far enough apart that their spheres of activity do not overlap, but the entire surface of the panel is covered with resonators. The surface of the panel, which supports the resonators is constructed as an absorber sheet that tightly surrounds the Helmholtz-resonators except for their respective openings. The Helmholtz-resonators and the absorber sheet are made of the same material.

It is important that the Helmholtz-resonators which are adjacent to and located within the sphere of activity of a low frequency Helmholtz-resonator have respectively different resonance frequencies, because Helmholtz-resonators of a lower resonance frequency have a larger sphere of activity than resonators of a higher resonance frequency. Otherwise, the resonance activity of the low frequency Helmholtz-resonators is substantially reduced. It is further important that the surface of the panel is substantially covered with a plurality of Helmholtz-resonators of different resonance frequencies in order to achieve an optimum acoustic efficiency within the available construction space for the panel. The tuning of the resonators may be readily achieved by a person skilled in the art given the well known Helmholtz equation.

It is a further important aspect of the present invention that the surface of the panel which supports the Helmholtz-resonators is constructed as an absorber sheet which tightly surrounds the resonators except for their openings. Consequently, the walls of the resonators are made of the material of the supporting absorber sheet. The term absorber sheet as used in this description defines a soft, pliable, sheet structure, which resonantly vibrates when subjected to sound, whereby the absorbed sound energy is converted to heat. Appropriate materials include all polymers in either foamed or compact condition. In comparison to a construction which only includes Helmholtz-resonators, the combination of Helmholtz-resonators and absorber sheets provides a further increase in the rate of absorption of about 30% of the normal value. Furthermore, it has been discovered that the sound scattering efficiency of a combination in accordance with the invention is unexpectedly higher than that of a sheet absorber or a Helmholtz-resonator construction in isolation.

The fact that the volume, opening radius and neck length of Helmholtz-resonators are variable provides for numerous possibilities for the variation of the resonance characteristics of a sound absorbing panel which is not too thick. The shape of the

Helmholtz-resonators may be arbitrarily selected, since it is the volume of a resonator that determines its resonance characteristics. Thus, extremely thin sound absorbing panels may be constructed. Such panels are especially useful for the sound insulation in the area around engines.

Furthermore, an overlap of the spheres of activity of the individual resonators permits for the production of sound absorbing panels which attenuate a wide range of sound frequencies while covering only a very small area.

It is another advantage of the present invention that the material of the Helmholtz-resonators is identical to the material of the absorber sheet. Thus, the selection of materials suitable for particular applications is facilitated. In addition, a sheet absorber/resonator combination in accordance with the present invention may be constructed in a single manufacturing process.

In a preferred embodiment of the invention, the surface of the absorber sheet that faces a sound source to be attenuated is covered with a porous layer that may be made of fibers or open celled porous foam. This porous layer provides for a further improvement in the absorption efficiency of the panel, especially at higher frequencies.

A shaped sound absorbing panel in accordance with the invention may be welded, clipped, or adhered to any desired base. When the base is pre-formed, as for example, in engine compartments, it is a further advantage of the present invention that the panel may be manufactured in the same process together with that part of the engine enclosure to which the sound absorbing panel is to be mounted. It is possible to adjust the sound absorption characteristics of a panel in accordance with the invention to the frequencies or frequency ranges to be attenuated within a frequency range of between 16 Hz and 2.5 kHz. This may also be specifically achieved in selected areas of the same sound absorbing panel.

Since the selection of the construction material for the panel is not critical, within the above described limits, a great liberty in the selection of the materials is provided. For example, a shaped sound absorbing panel may be made of oil, water and heat resistant material if it is to be installed in close proximity to an engine. The panel may also be used for the sound insulation of machines, for example, in the housings of household or industrial appliances and/or machines.

The invention will now be further described by way of example only and with reference to the following drawings, wherein

Figure 1 shows a cross-section through an engine shield made of a sound absorbing panel in accordance with the invention;

Figure 2 illustrates the assembly of the embodiment shown in Figure 1;

Figure 3 shows an engine shield in accordance with the invention, in an installed condition;

Figure 4 illustrates an enlarged cross-section through a sound absorbing panel in accordance with the invention;

Figure 5 is a cross-section through an absorber combination in accordance with the present invention; and

Figure 6 shows a panel in accordance with the invention made of plastic foam.

In a preferred embodiment of the invention as illustrated in Figure 1, the sound absorbing panel in accordance with the invention is employed as an engine sound shield and is manufactured in a single process using gas injection techniques known in the art. Chambers 1,

which are of different volume and cover the entire surface of the sound absorbing panel, have bores 2 of a selected diameter between 1 and 20 mm. The chambers 1 act as Helmholtz-resonators for noise reduction in an engine compartment. An outer skin 3 of the panel has a smooth outer surface, which improves its aerodynamics. In order to achieve a good sealing engagement with the body of the vehicle, an elastic sealing lip 4 is positioned into the forming tool and incorporated into the panel during production thereof. Slots or bores 5 are provided at the lowest point on an installed panel to permit the drainage of liquids such as splash water or leaked oil, which may enter the element through bores 2. The material of the outer skin 3 is glass fiber and the material of the resonators is reinforced polypropylene. Polycarbonates or polyamides may also be used without difficulty.

At this point it must be emphasized that the connection between the chambers along the bottom of the Helmholtz-resonators as shown has no effect on the damping characteristics of the panel. The layers of air located along the inner surface of outer side 3 are not excited by the sound impinging on the panel. Thus, this connection of the chambers 1 along the inner surface of the outer skin 3 may be used for drainage.

Figure 2 shows a cross-section through an engine sound shield, which is manufactured in a two-step process wherein the outer skin 3 and the inner skin 6, which includes the resonator chambers 1, are connected through welding or gluing. The inner skin 6 with its chambers 1 and their bores 2 is manufactured and tuned separately. As is apparent, the inner skin 6 defines each resonator chamber 1 by a respective lateral wall 9 such that adjacent resonators do not have a common wall. The outer skin 3 including the attached sealing lip 4 is also separately manufactured. The outer and inner skins are interconnected through welding or gluing techniques and afterwards form a unit as shown in Figure 1.

Figure 3 illustrates the element of Figure 1 or 2 in its installed condition above an automobile engine. The hood 7 which

corresponds to outer skin 3 is made of sheet steel and is formed in one manufacturing process together with the Helmholtz absorber chambers 1 and their bores 2.

Figure 4 is a schematic illustration of an enlarged cross-section through a number of Helmholtz-resonators. Chambers 1 are of different size and the dimensions of bores 2 are selected in accordance with the Helmholtz equation.

Figure 5 shows an absorber combination which provides especially efficient sound absorption. The basic construction of the absorber including chambers 1 and their openings 2 may be manufactured through vacuum molding, pressing, injection shell molding or gas injection. In addition, the surface of the element which is adapted to face a sound source is covered with a fleece material 8 which is provided with a binder.

Figure 6 is a cross-section through a sound absorbing panel, which is manufactured from plastic foam in a single process. The plastic may be polystyrene, polyethylene or polypropylene, depending on the application of the panel. The chambers 1 are of different size. The openings of the Helmholtz-resonators are indicated by reference numeral 2.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A sound absorbing panel for the absorption of airborne sound emanating from a sound source, comprising:

a panel surface adapted to face the sound source, the surface including a plurality of Helmholtz resonators with different resonance frequencies;

each Helmholtz resonator having a sphere of activity and being so positioned that adjacent Helmholtz resonators of the same frequency do not have overlapping spheres of activity.

2. A panel as claimed in claim 1, wherein a surface of the panel surface adapted to face a sound source is covered with a porous layer.

3. A panel as claimed in claim 2, wherein the porous layer is a fiber fleece material.

4. A panel as claimed in claim 2, wherein the porous layer is made of open-cell foam material.

5. A shaped article for absorption of airborne sound emanating from a source, said article comprising:

a plate-type absorber formed of a material having a surface facing the source of the sound, and

a plurality of Helmholtz resonators having openings on said surface, each said Helmholtz resonator having an action range and a resonant frequency which is different from the resonant frequency of any other resonator in the action range of the respective each said Helmholtz resonator, each said resonator being defined by a respective lateral wall such that adjacent resonators do not have a common wall.

6. A shaped article as claimed in claim 5, characterized in that on its side facing toward the source of the sound, the plate-type absorber is covered with a porous layer.

7. A shaped article as claimed in claim 6, characterized in that the porous layer is a nonwoven material.

8. A shaped article as claimed in claim 7, characterized in that the porous layer is an open-pore foam.

9. A shaped article as claimed in claims 5, 6, 7 or 8 wherein the plate-type absorber and the Helmholtz resonators are made of the same material.

10. A shaped article as claimed in claim 5 wherein said openings are circular.

11. A sound absorbing panel for absorption of airborne sound emanating from a sound source, comprising:

a plate-type absorber formed of a material having a surface facing the sound source;

the plate-type absorber forming a plurality of Helmholtz resonators on the surface;

each Helmholtz resonator having an opening which pierces the surface and communicates with a chamber defined by the resonator, the opening in the chamber being tuned to a resonant frequency and having a sphere of activity;

the Helmholtz resonators being so positioned on the surface that resonators having the same resonant frequency do not have spheres of activity which overlap; and

each Helmholtz resonator is defined by a respective lateral wall such that adjacent resonators do not have a common lateral wall.

12. A sound absorbing panel as claimed in claim 11 characterized in that on its side facing toward the source of the sound, the plate-type absorber is covered with a porous layer.

13. A sound absorbing panel as claimed in claim 12, characterized in that the porous layer is a nonwoven material.

14. A sound absorbing panel as claimed in claim 13, characterized in that the porous layer is an open-pore foam.

15. A sound absorbing panel as claimed in claims 11, 12, 13 or 14 wherein the plate-type absorber and the Helmholtz resonators are made of the same material.

16. A sound absorbing panel as claimed in claims 11, 12, 13 or 14 wherein said openings are circular.

Fig. 1

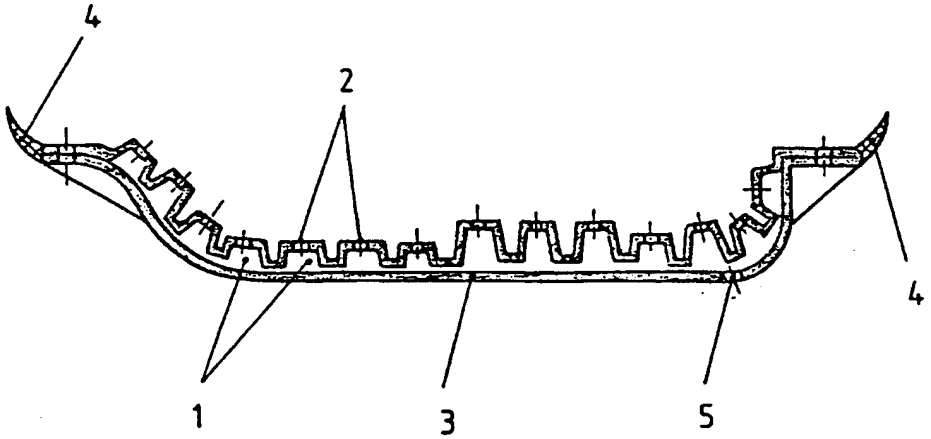

Fig. 2

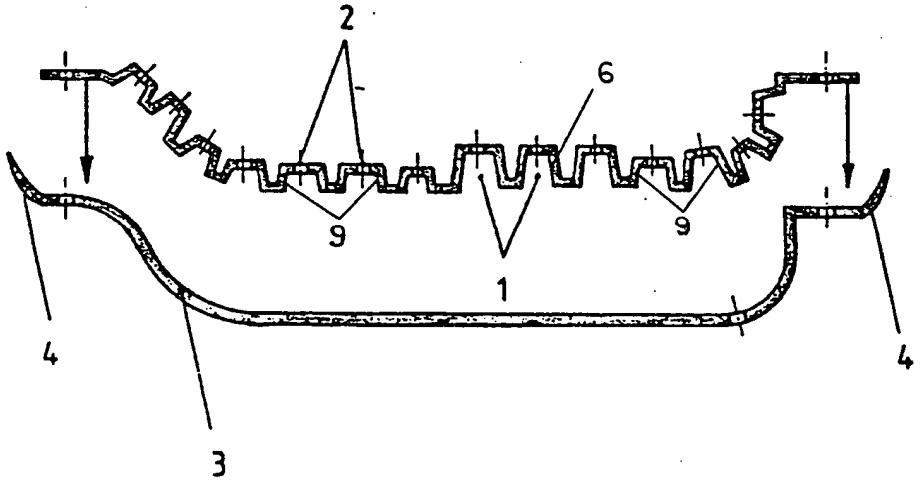

Fig. 3

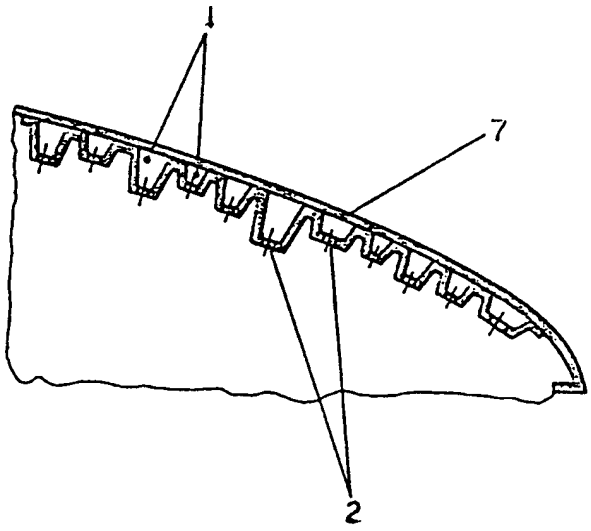

Fig. 4

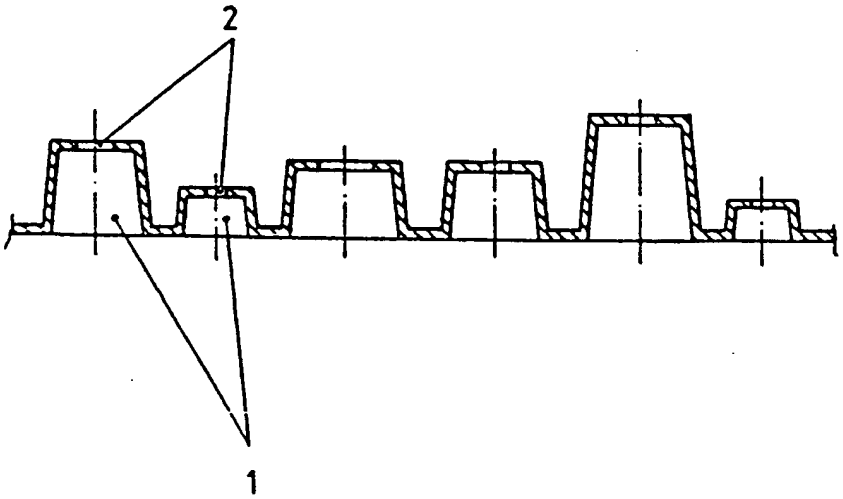

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Fig. 5

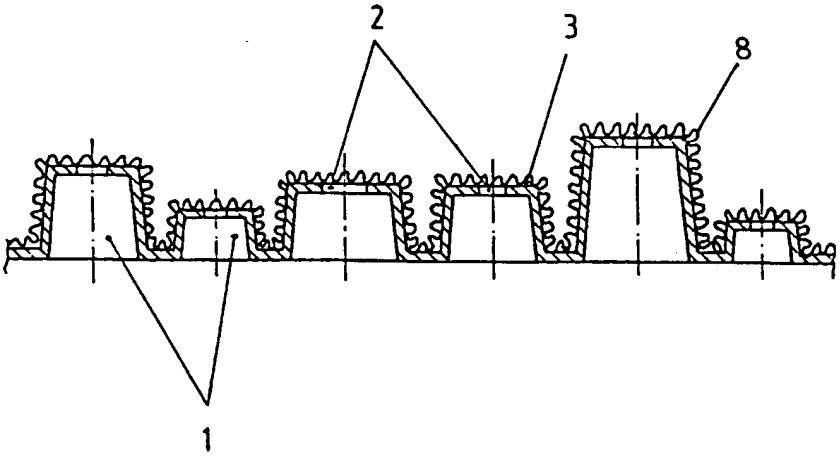

Fig. 6